Photon Detector Calibration Monitoring System

Zelimir Djurcic, Gary Drake, Steve Magill,
Vic Guarino, Aleena Rafique, Jaroslav Zalesak
(for the Photon-Detector Consortium)

Photon-Detector Calibration Monitoring

Motivation

- Verify the photon detector gain, linearity, and timing resolution
- Monitor stability and response over time
- Use the UV calibration/monitoring system as the detector commissioning tool: before closing the cryostat, in the cool-down phase, and when filled with LAr- to test the photon detectors
- Generate test conditions for low-energy physics
- Make use of it for quick reliable test of PDS when a change is made

  => Don't have to wait for cosmic muon coverage of entire detector

R&D on Photon-Detector Calibration Monitoring

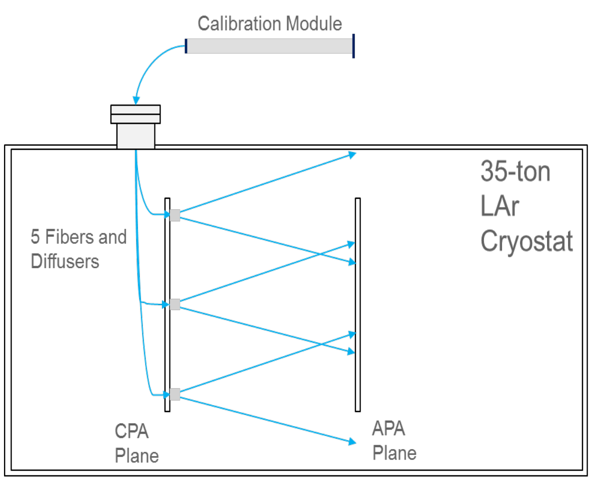
-System prototyped and operated with 35t DUNE detector, data analyzed and published

-System designed and implemented in ProtoDUNE-SP, data being collected, to be analyzed

UV Light Calibration Monitoring System

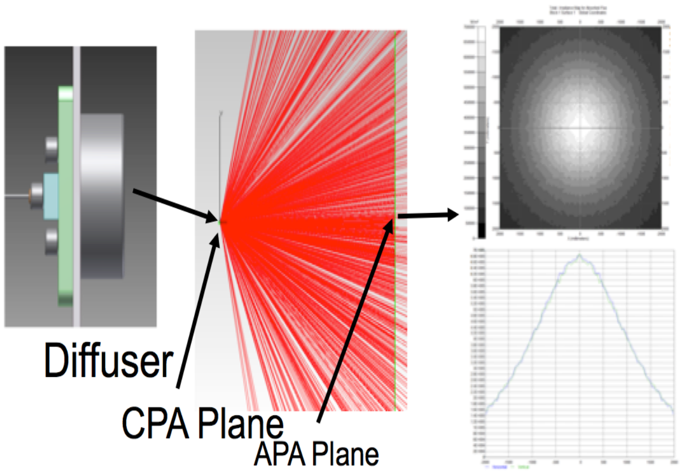
- Photon Detector Calibration Monitoring System has been realized in a form UV-light flasher calibration system
- UV light calibration system design:

-transports light from 275 nm UV LED sources (so-called Calibration Module) through quartz fibers to the TPC volume
-diffuse light to the photon detection system light collection elements located at APA
-use UV light to be wavelength shifted with photon-collector components of photon detector
-observe SiPM response to shifted light.



➢ Outer Components:
-Calibration Module with 275nm LEDs
-Optical quartz fiber for light transport

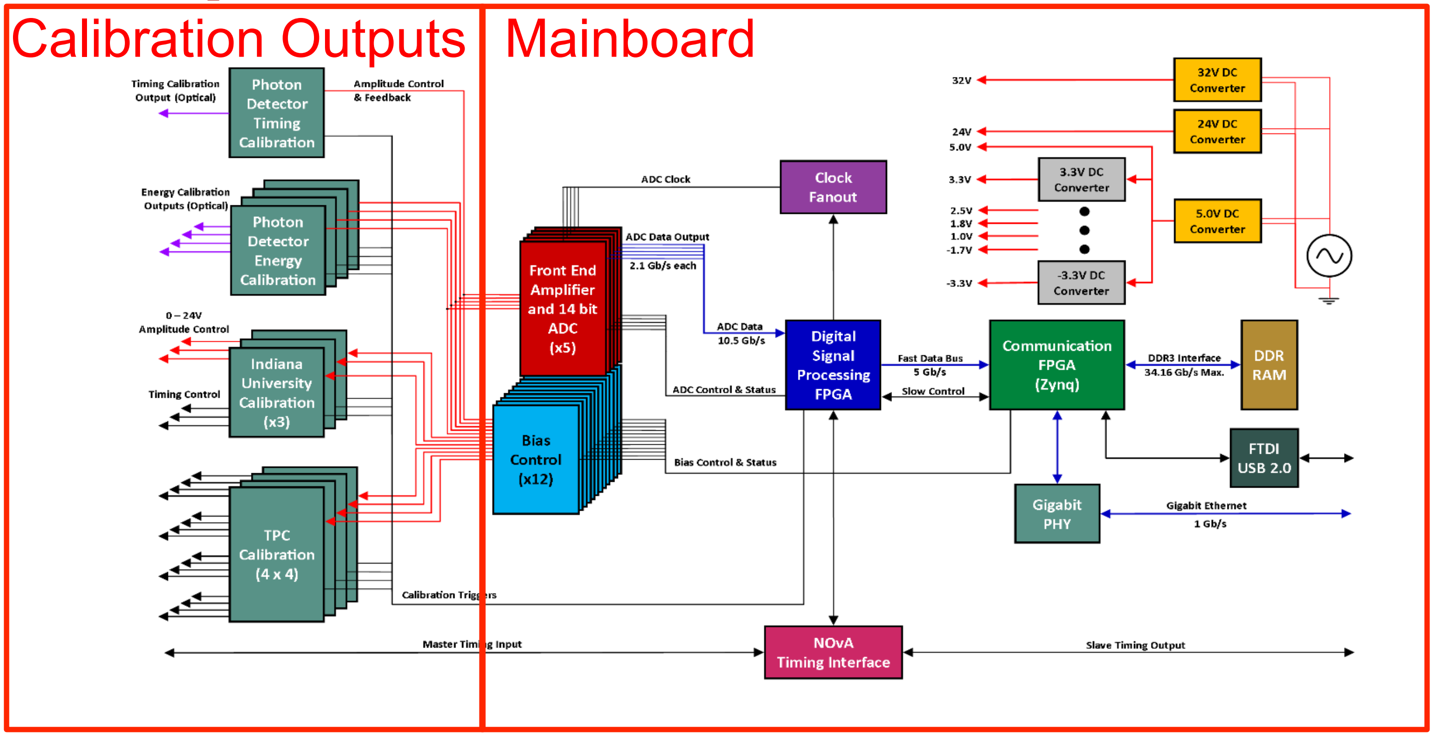
➢ Inner Components:
-Flange with optical fiber feed-through
-Optical quartz fiber for light transport
-Light diffusers at CPA plane

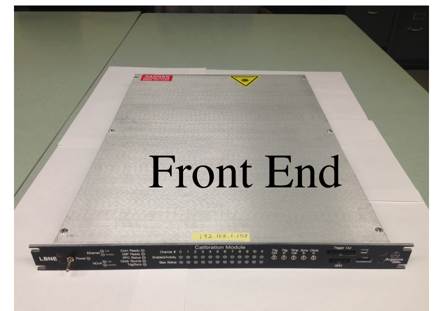


Optical Simulation of Single Diffuser at APA distance

DUNE Calibration Module

- Utilizes the SSP mainboard as a controller
  -Ethernet communication, timing control, internal/external triggering, etc.
- Light source controllable in terms of pulse height, pulse width, pulse repetition rate, single or double pulses.





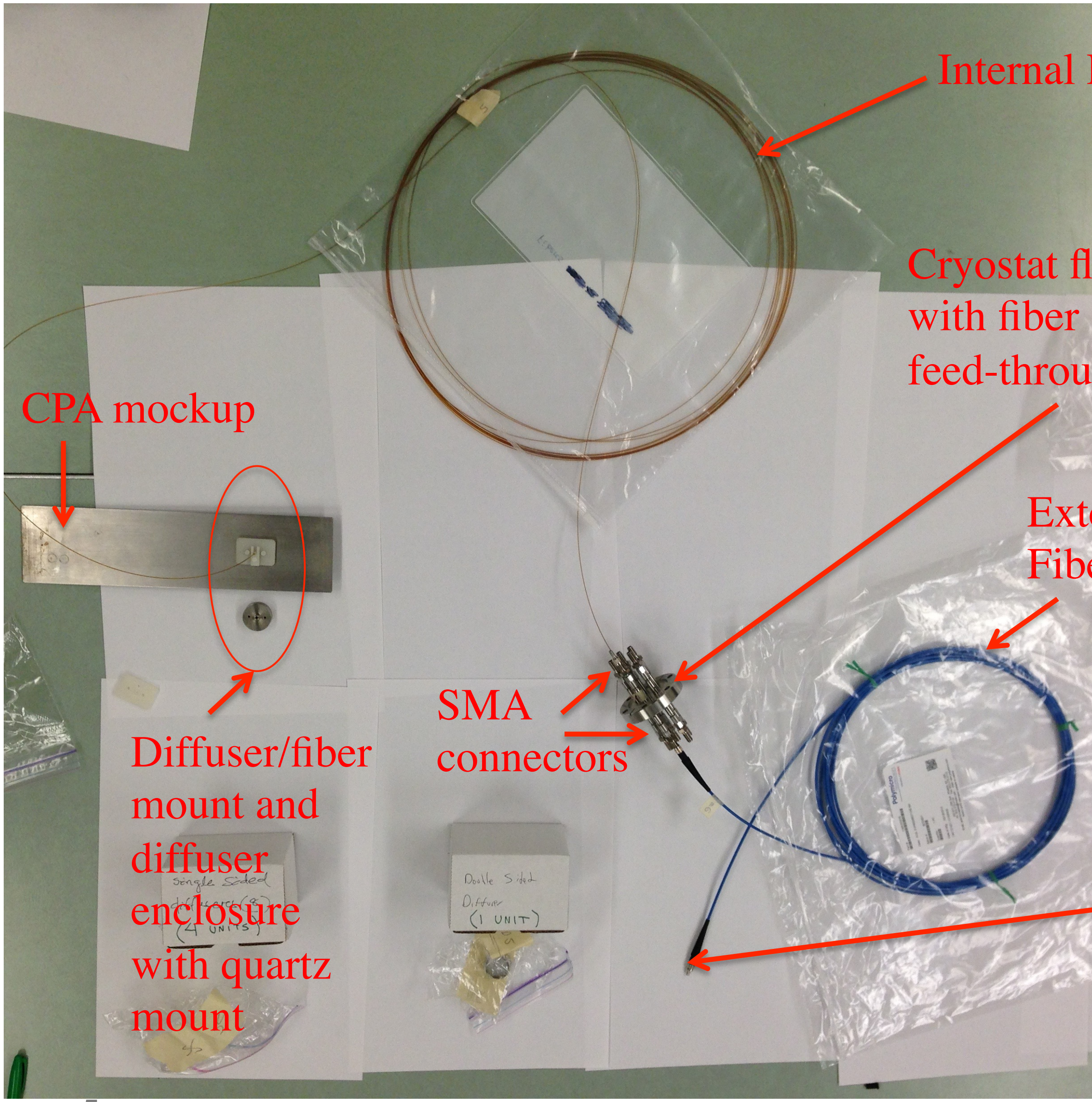
Fiber SMAs

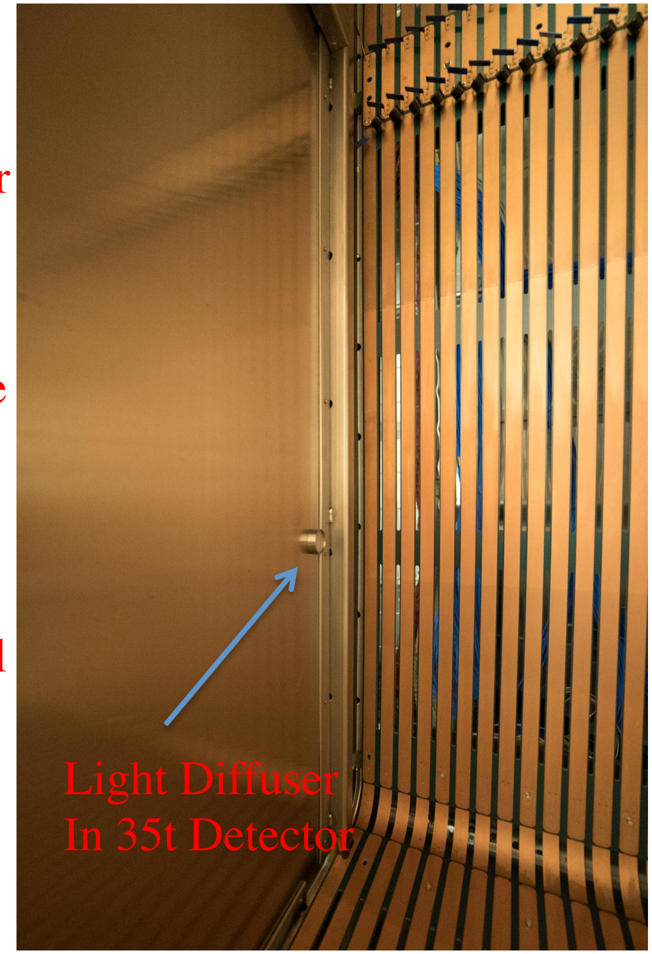
(also see the Backups)

Calibration Back-Panel

Components of the PD UV Calibration System

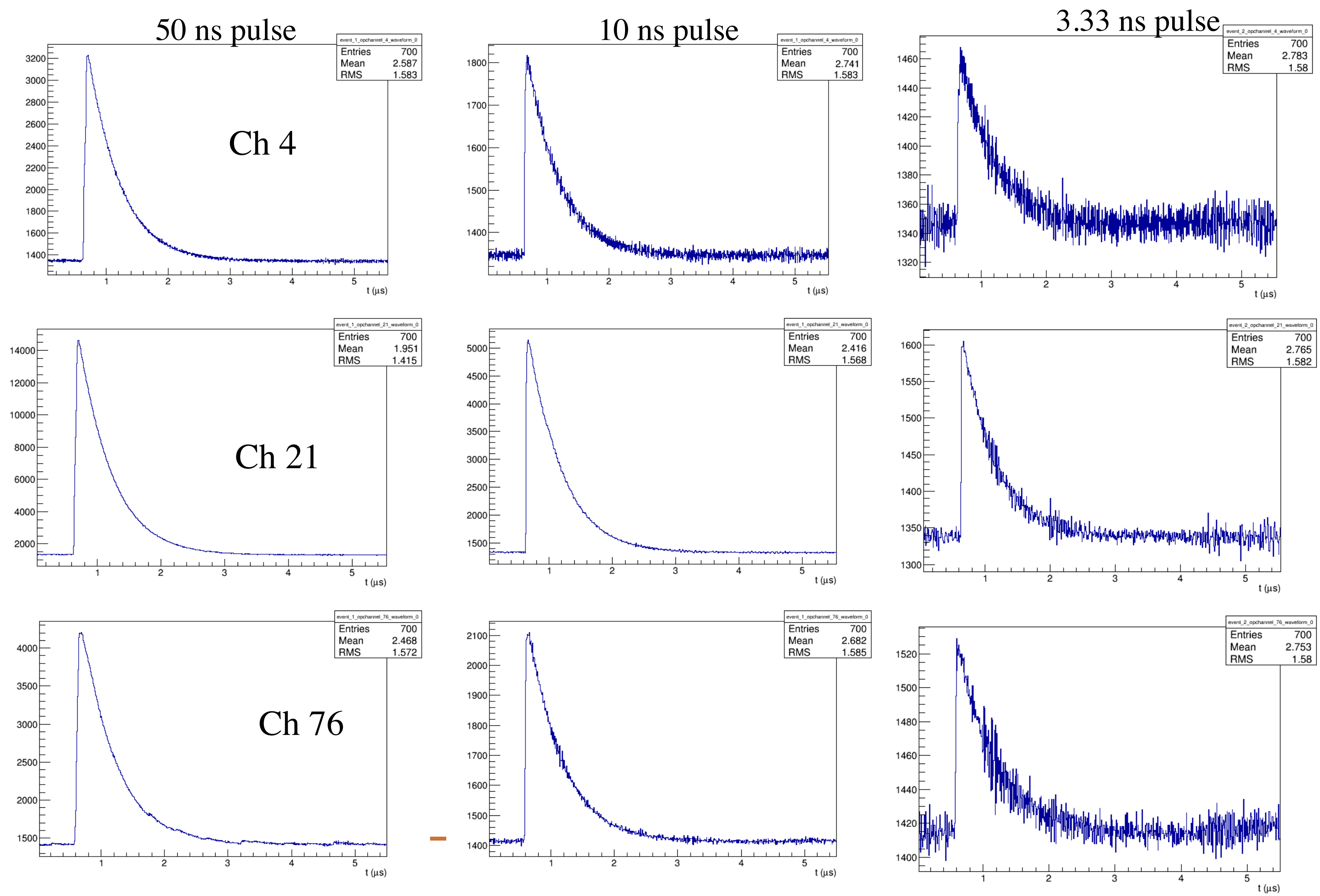
- Components installed with 35t DUNE prototype





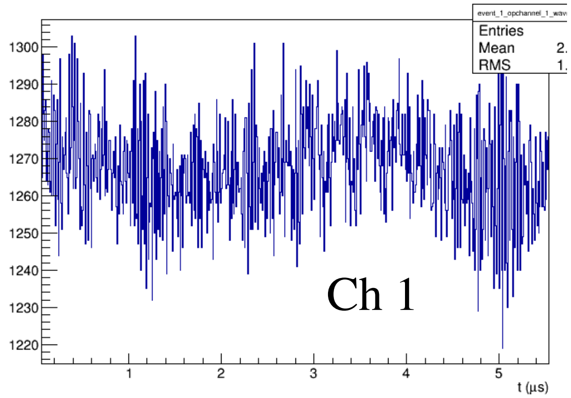
35-ton Experience (I)

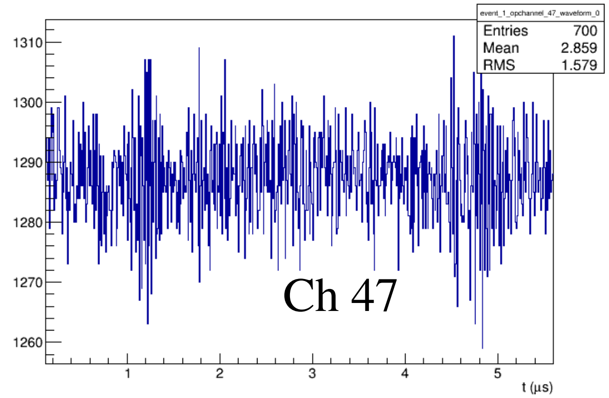
- Identified Standard PDS Channels



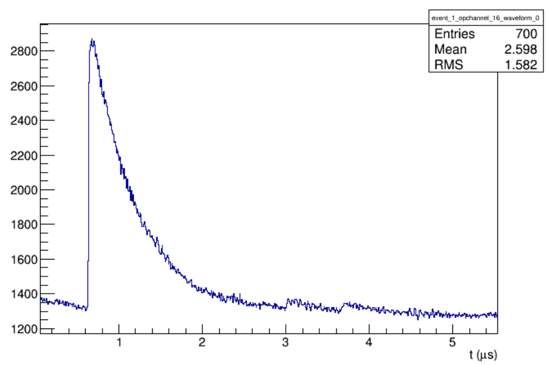
35-ton Experience (II)

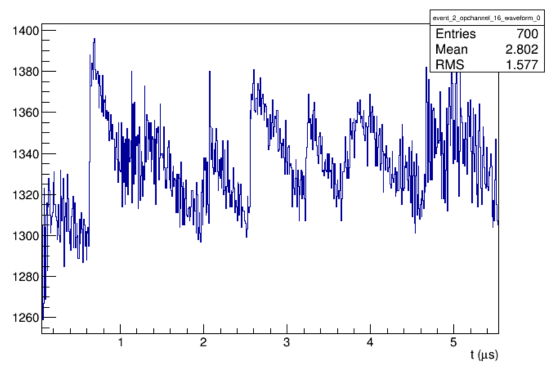
- Identified Malfunctioning PDS Channels



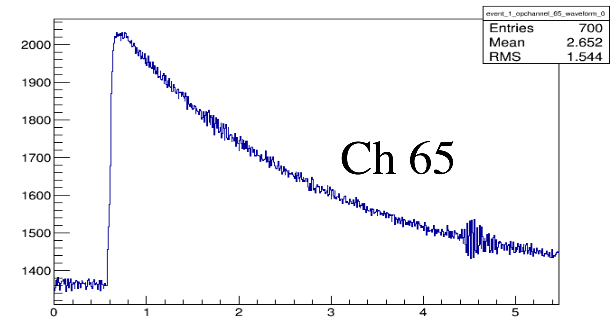


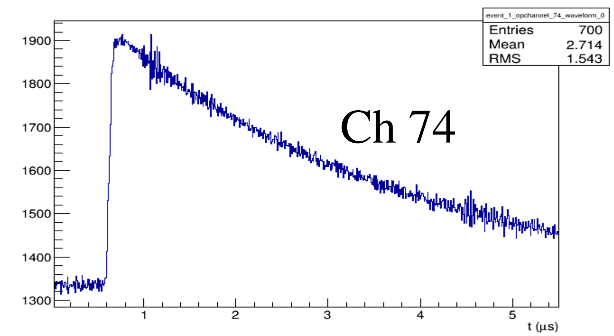
- Channels with p.e.-like noise





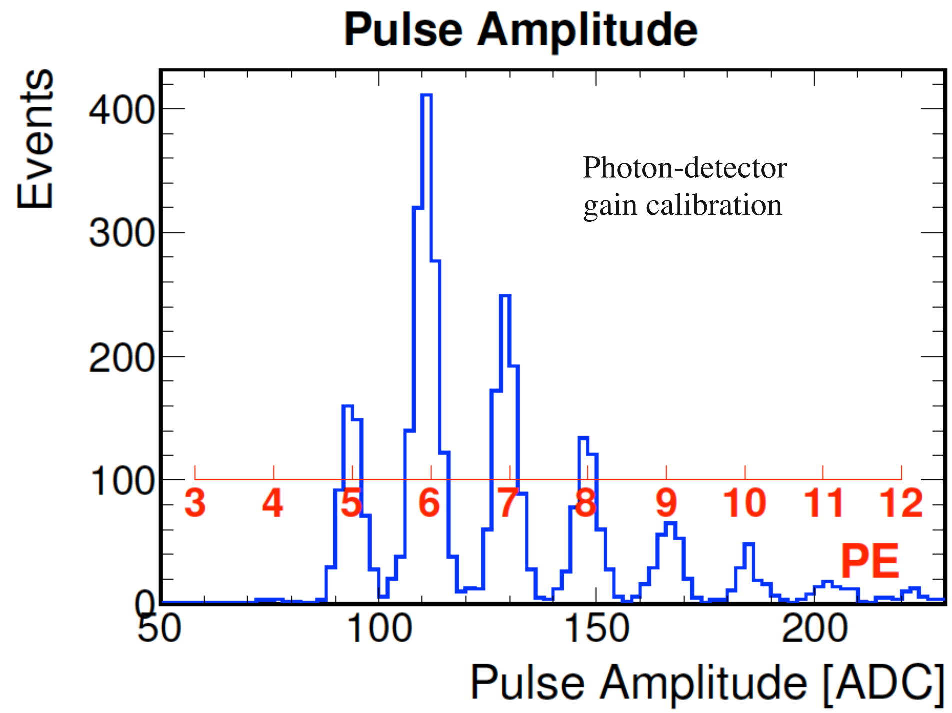
- "Slow" PD Channels

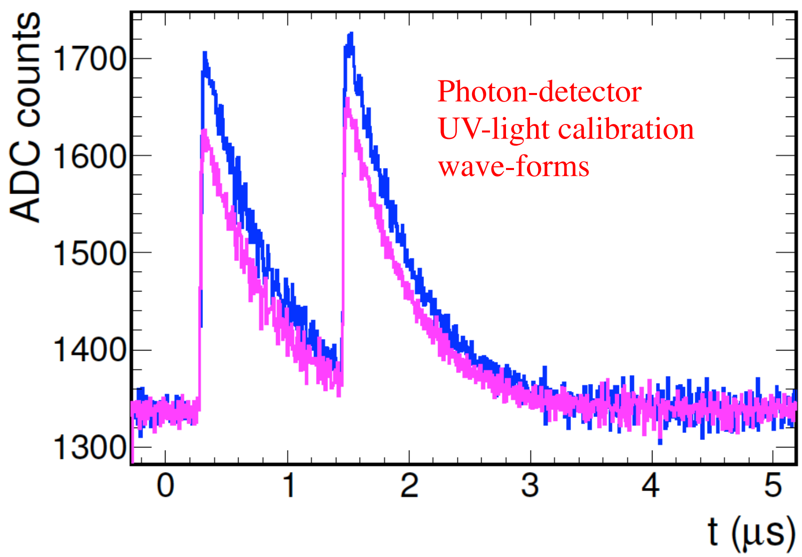


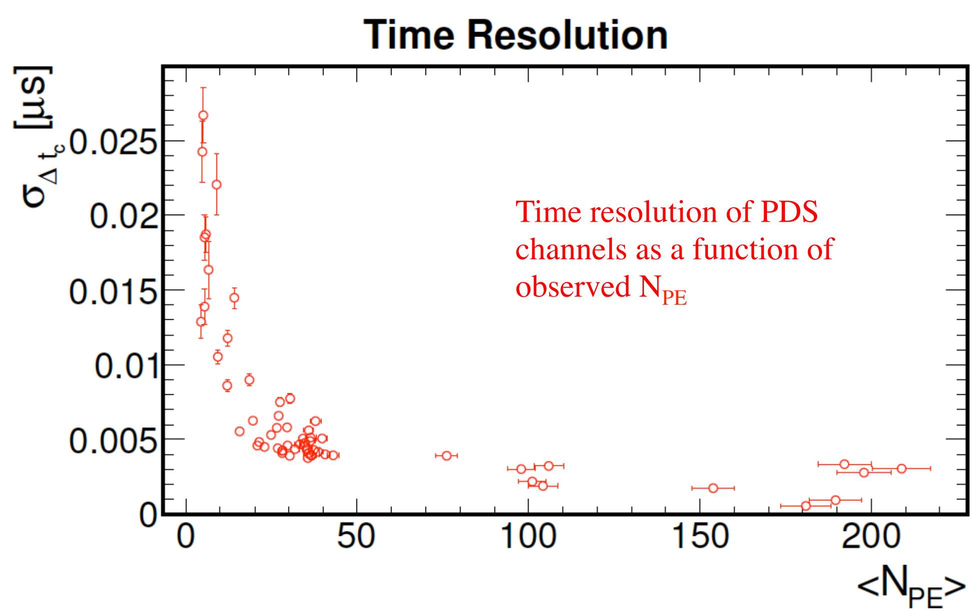


35-ton Experience (III)

- Example uses of PDS Calibration System
  published in JINST,
  arXiv:1803.06379

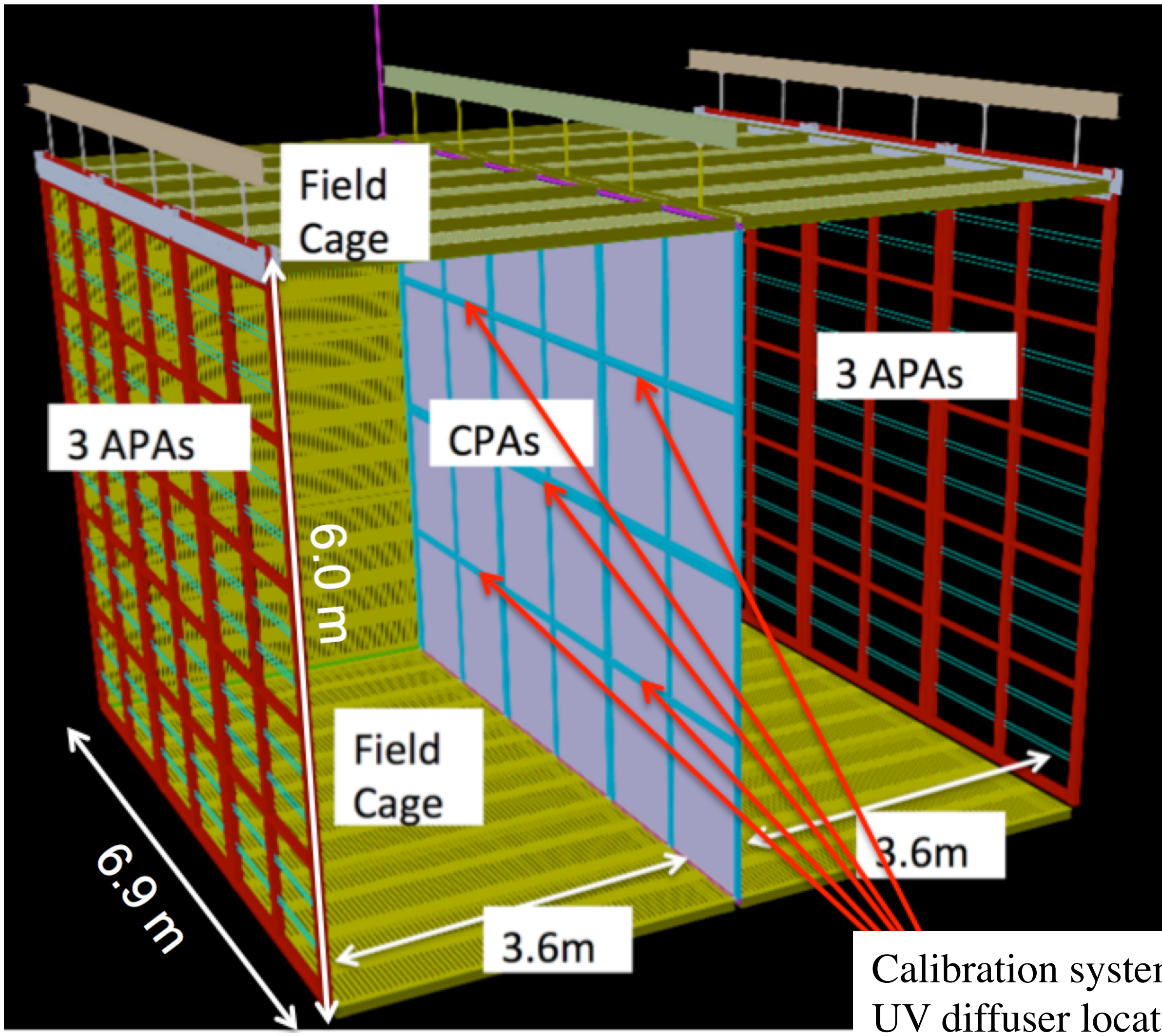


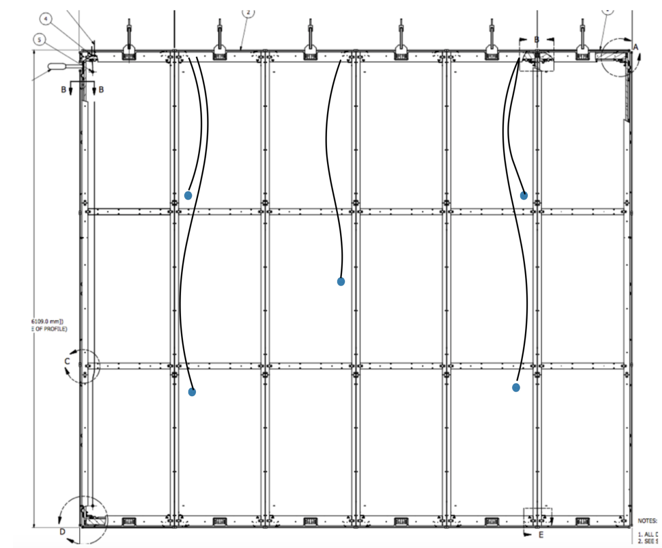




ProtoDUNE Design (I)

- Photon-Detector Calibration system with light emitted from CPA to APAs

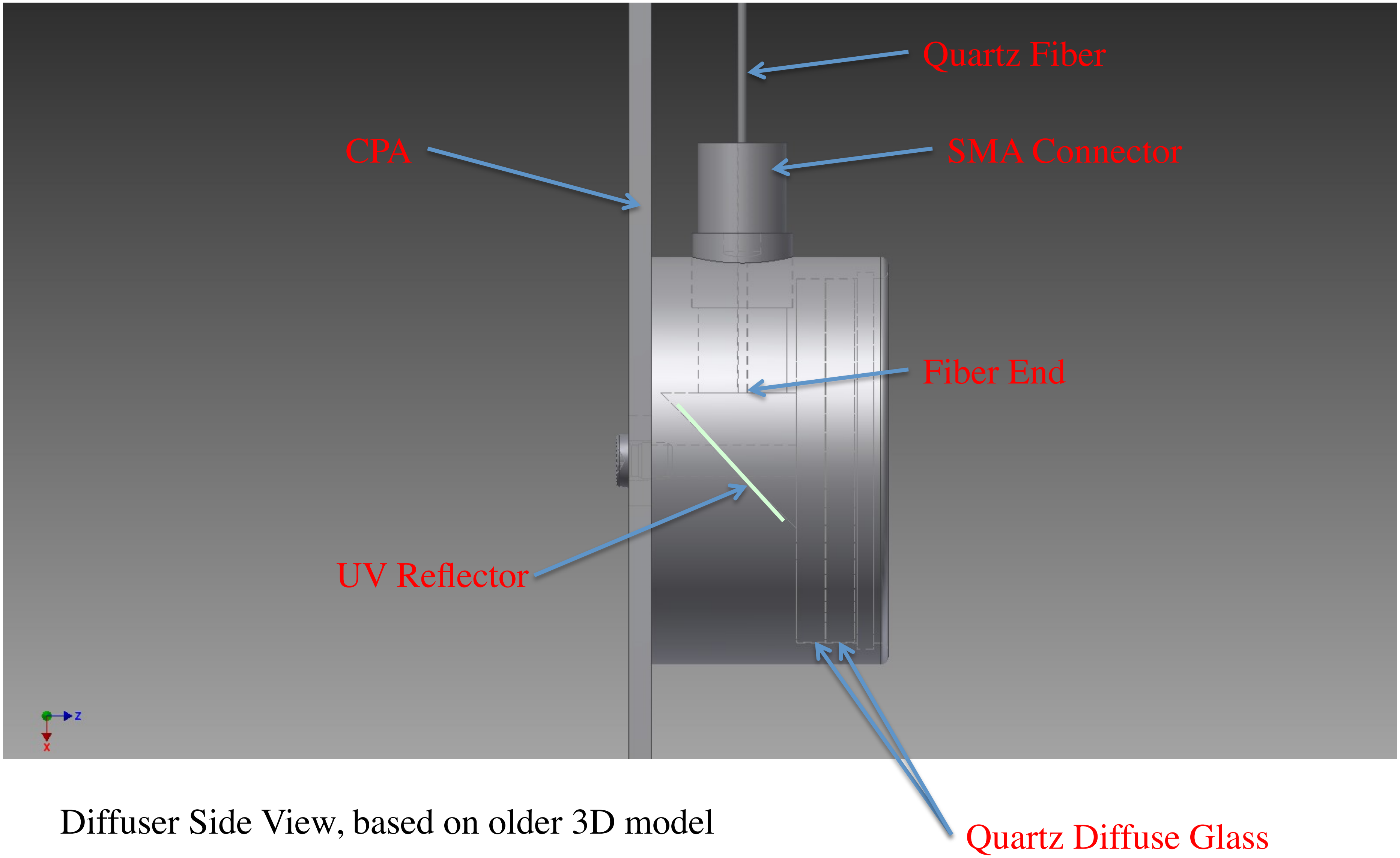




Calibration system:
UV diffuser locations
at ProtoDUNE-SP CPA

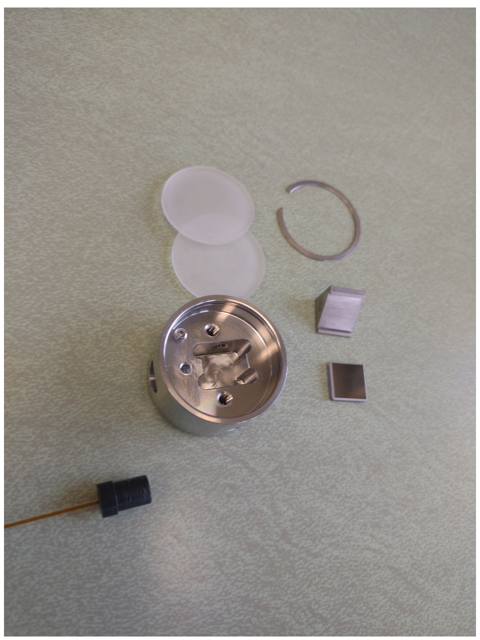
ProtoDUNE Design (II)

- Diffuser Design for ProtoDUNE's CPA



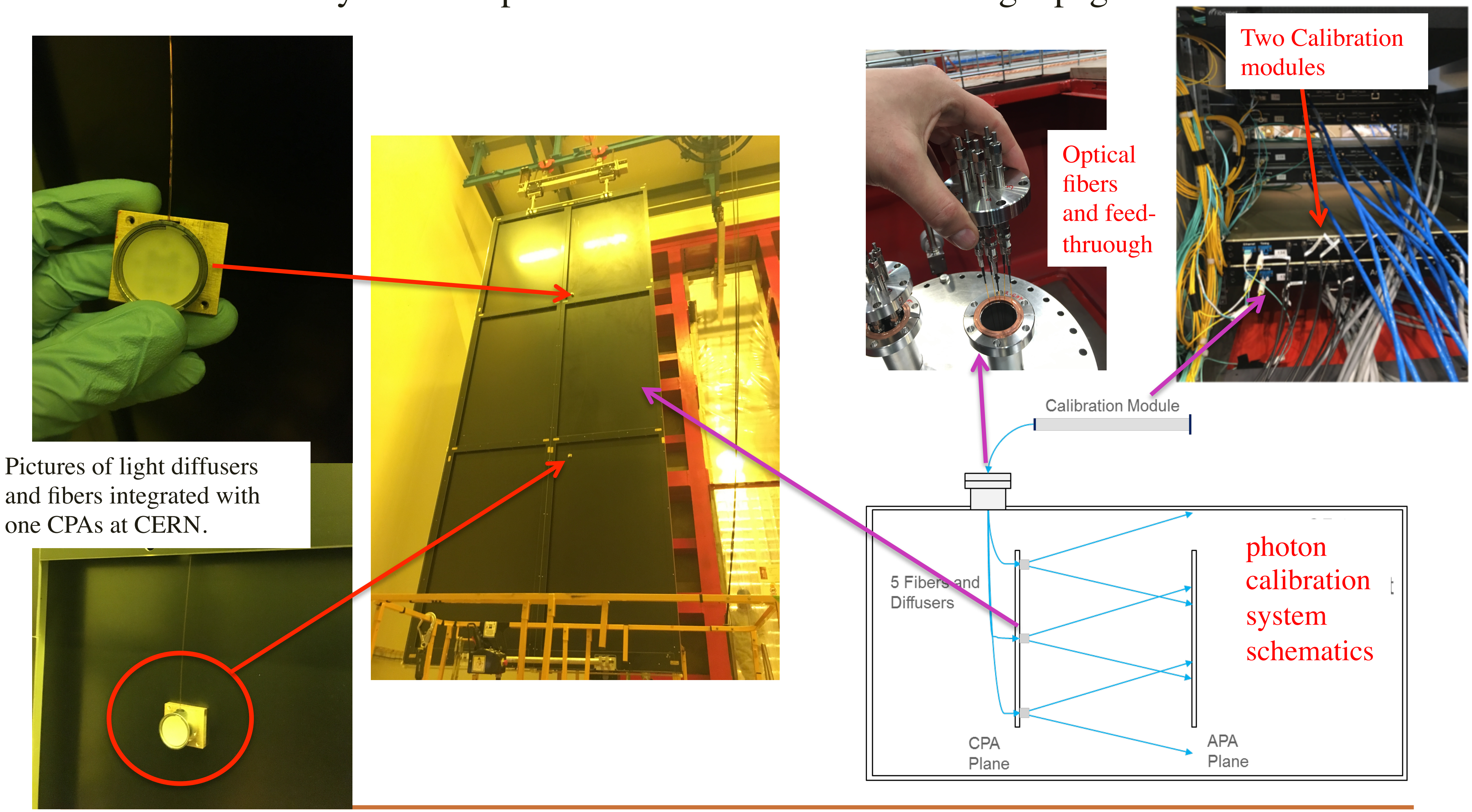
Diffuser Side View, based on older 3D model

ProtoDUNE Design (III)



ProtoDUNE Design (IV)

- Prototype of the system completed (designed, fabricated, installed) for ProtoDUNE
  - ➢ ProtoDUNE system components illustrated here in the single page



ProtoDUNE Design (IV)

- Prototype of the system completed (designed, fabricated, installed) for ProtoDUNE
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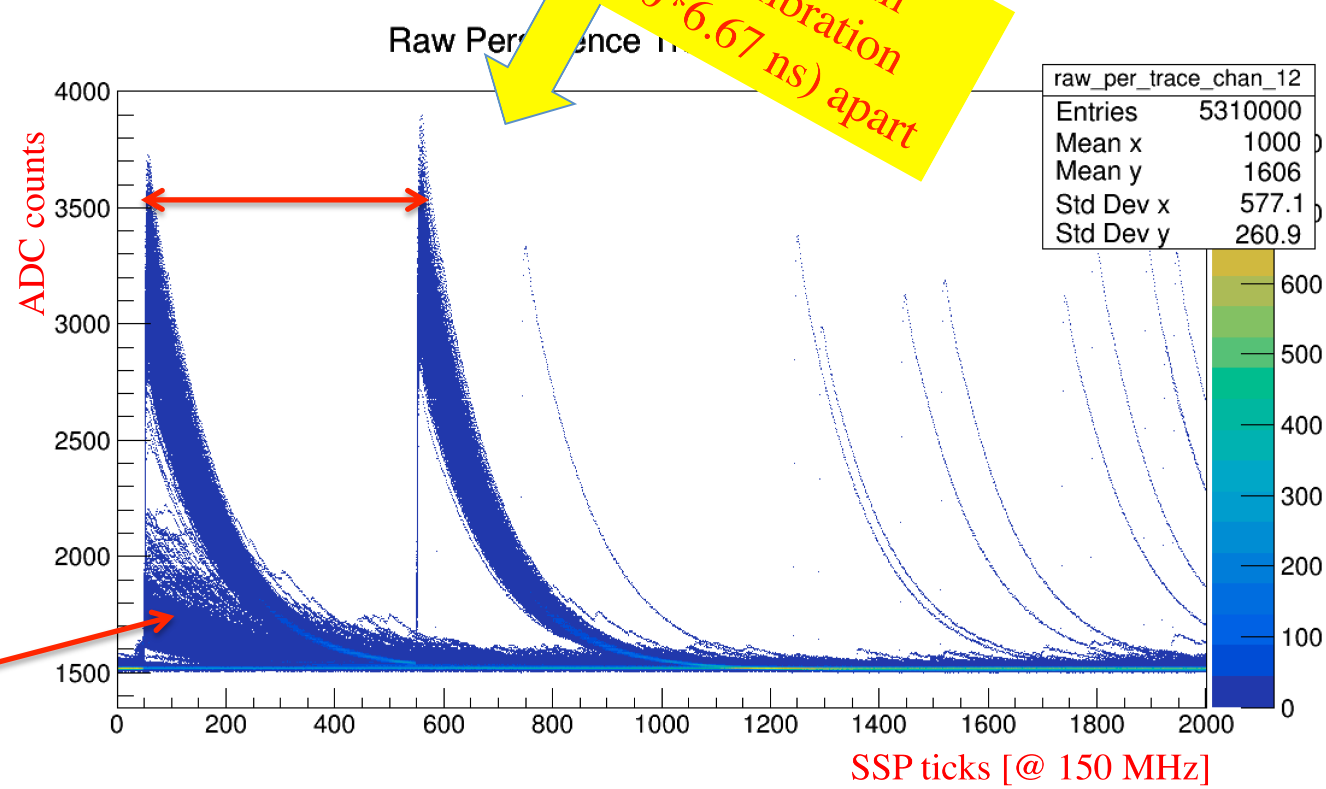
Typical photon-detector waveform as a response to a pair of calibration pulses at 500 ticks (500*6.67 ns) apart



"Accidental" cosmic ray muons

Status of ProtoDUNE-SP Monitoring System

- ProtoDUNE Calibration/Monitoring system is operational
  - -The system run through DAQ, emitting light from calibration modules, through warm fibers, feed-through, cold fibers, to diffusers, and to photon-detectors within APA
  - -Light observed by photon-detector modules and readout by SSPs

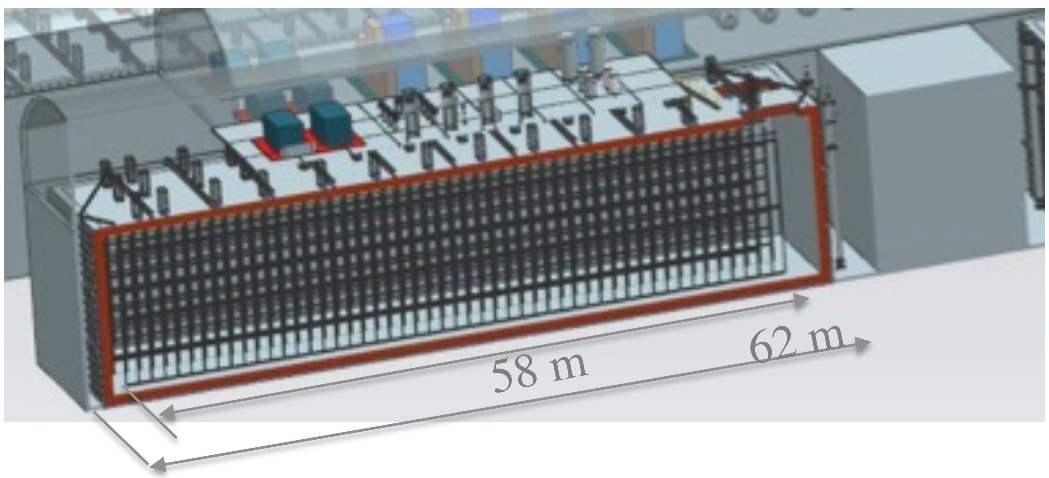
- No HV issues observed with fibers/diffusers (at 180 kV)

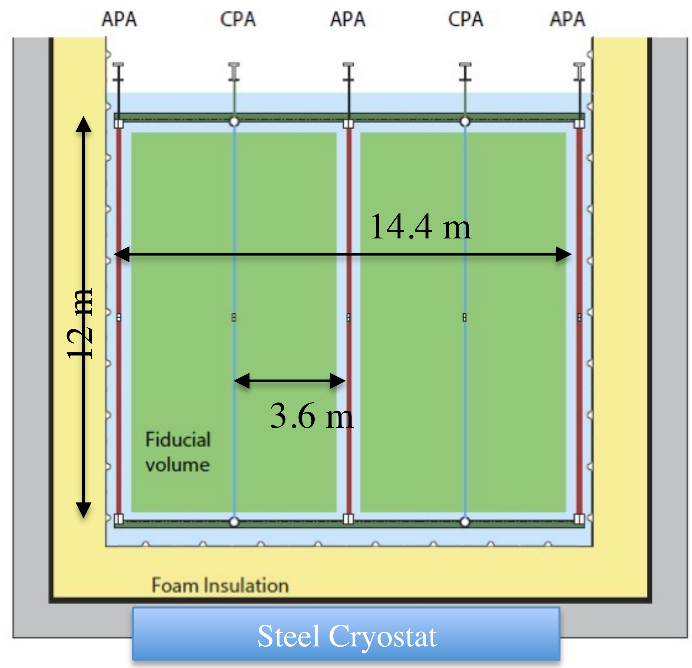
- Next steps: continue to optimize photon-detector configuration in ProtoDUNE
  - -Collect ProtoDUNE calibration system data at various pulse heights, pulse widths, at different repetition rates
  - -Analyze data to evaluate gain and channel-to-channel timing, and relative efficiency of photon-detectors
  - -Understand a map of diffuser positions we need for DUNE

- Use ProtoDUNE experience/expertise for design of the DUNE photon-detector calibration/monitoring system

DUNE photon monitoring system

- Using ProtoDUNE to optimize the requirement for DUNE PDS calibration monitiring system





- 3 Anode Plane Assemblies wide (3.6 m drift length)
- CPAs are internal
- 58 m long x 12 m high

- Diffusers on both sides of one CPA
- Only one side for other CPA

DUNE FD Cryostat Penetrations

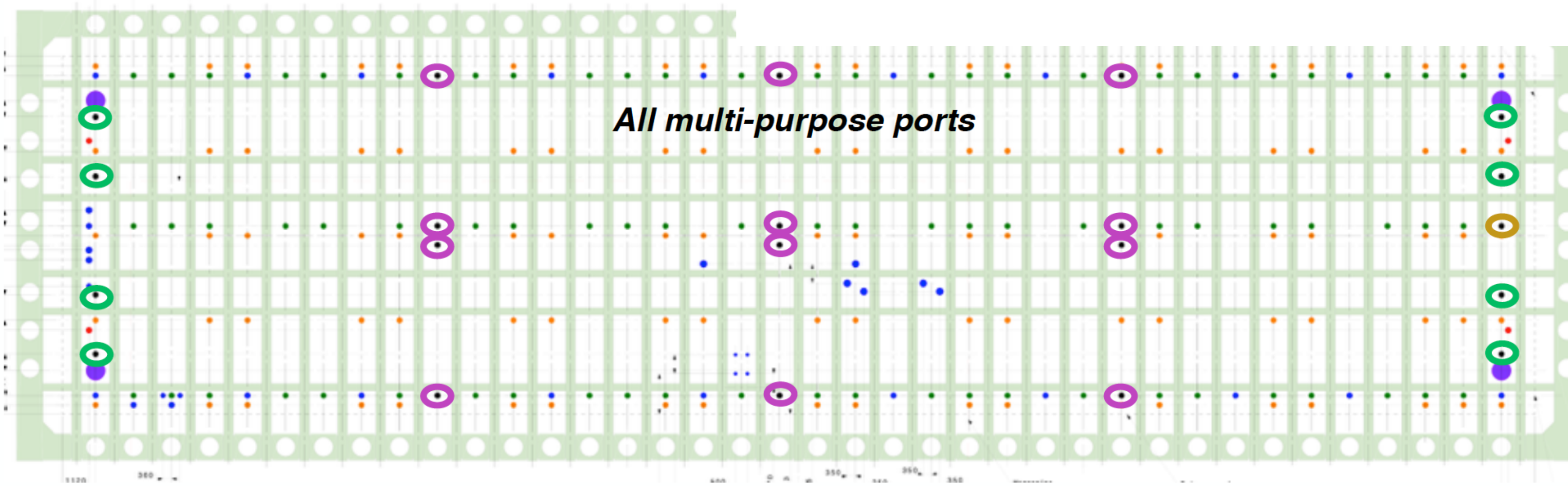
Slide from Sowjanya's DUNE Collaboration Meeting talk:

https://indico.fnal.gov/event/14581/session/0/contribution/10/material/slides/0.pdf

= Calibration FTs

= Calibration FT (outside the FC)

= Cryogenic Instrumentation FT



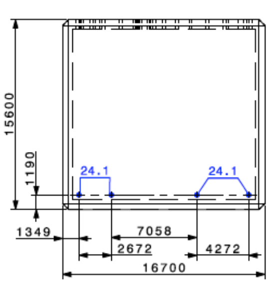
Pos.	Diameter [mm]	Quantity	Description
1	Ø250	100	Support
2	Ø250	75	Cable
3	Ø250	4	High voltage
4	Ø250	21	Instrumentation
5	Ø800	4	Manholes

Laser FTs (Magenta & Green) every 14 m or so. 10 m laser range demonstrated in MicroBooNE.

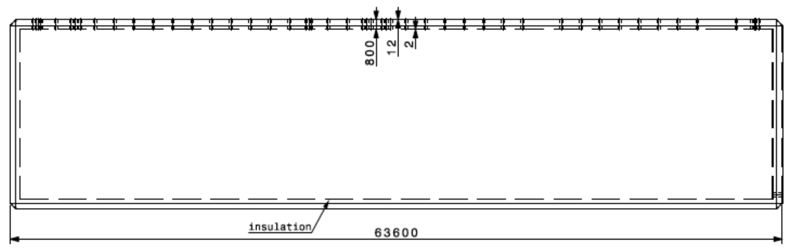
DUNE FD Cryostat Penetrations

(updated drawings)

Right view
1:200



Front view
1:200

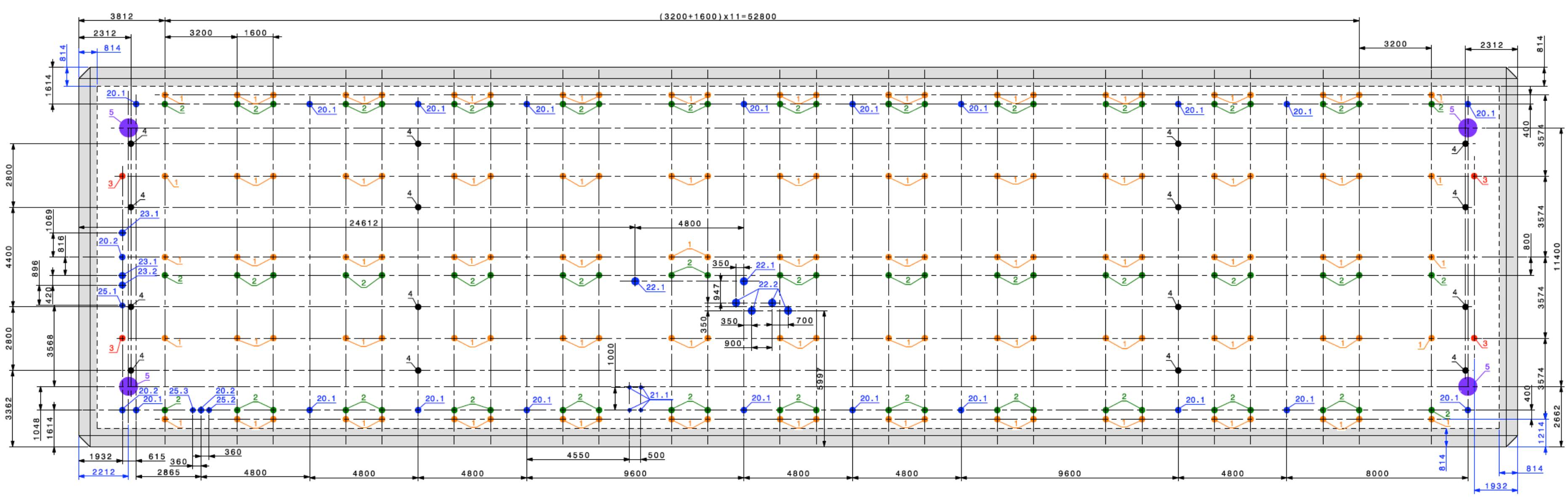


Detector penetrations

Pos.	Diameter [mm]	Quantity	Description
1	Ø250	120	Support
2	Ø250	72	Cable
3	Ø250	4	High voltage
4	Ø250	16	Instrumentation
5	Ø800	4	Manholes

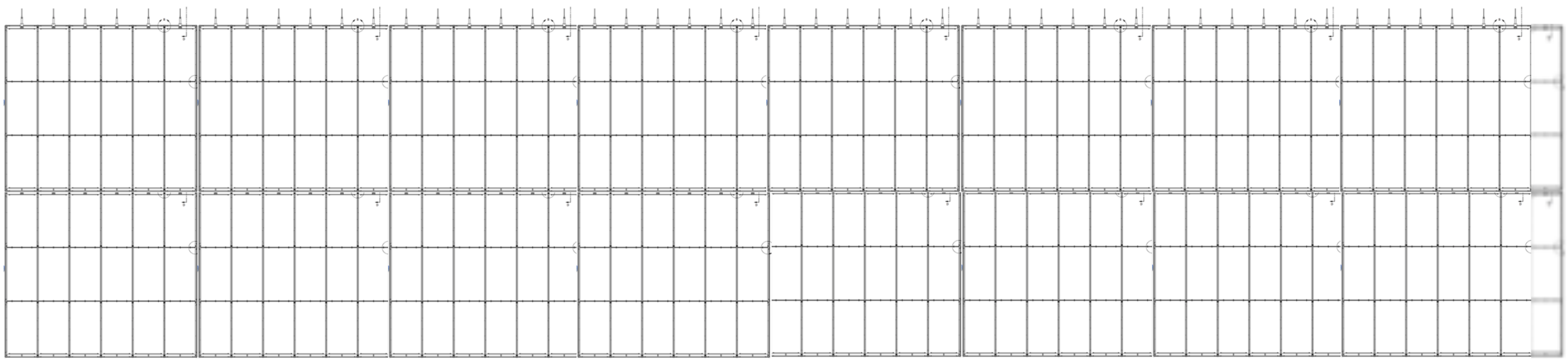
Cryogenic penetrations

Pos.	Diameter [mm]	Quantity	Description
20.1	Ø250	20	L+G Ar cool down
20.2		3	Spare
21.1	Ø152	4	G Ar Controled vent
22.1	Ø324	2	G Ar Boil off
22.2		4	G Ar Relief/Safety
23.1	Ø273	2	L Ar Return
23.2		1	L Ar Emergency return
24.1	Ø350	4	L Ar Pump
25.1	Ø219	1	G Ar Purge
25.2		1	G Ar Make up
25.3		1	G Ar Momentum



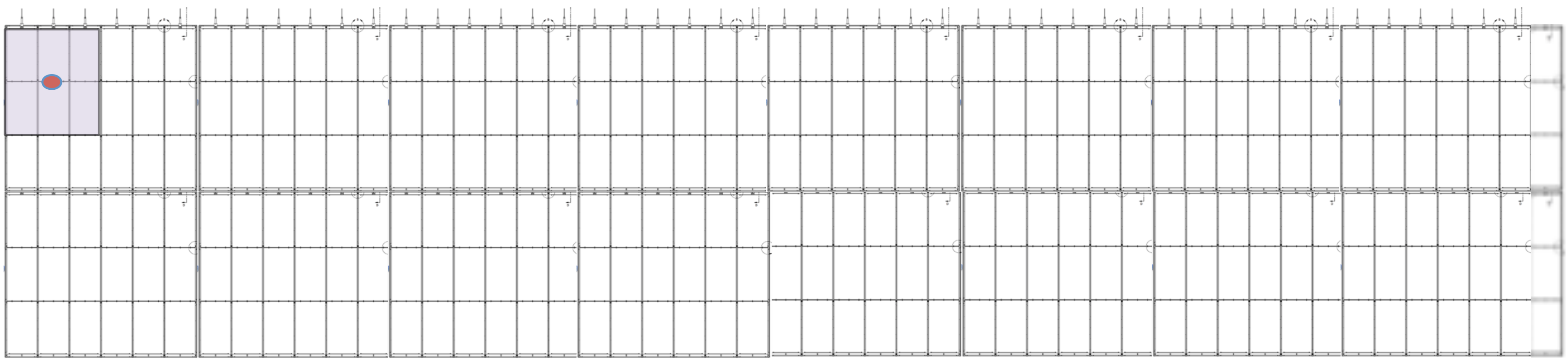
DUNE photon monitoring system

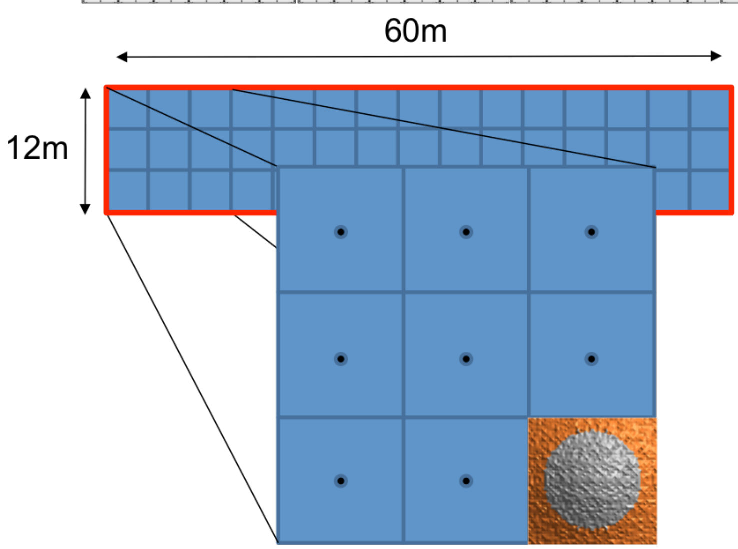
- Side view of one DUNE CPA Panel



DUNE photon monitoring system

- Side view of one DUNE CPA Panel

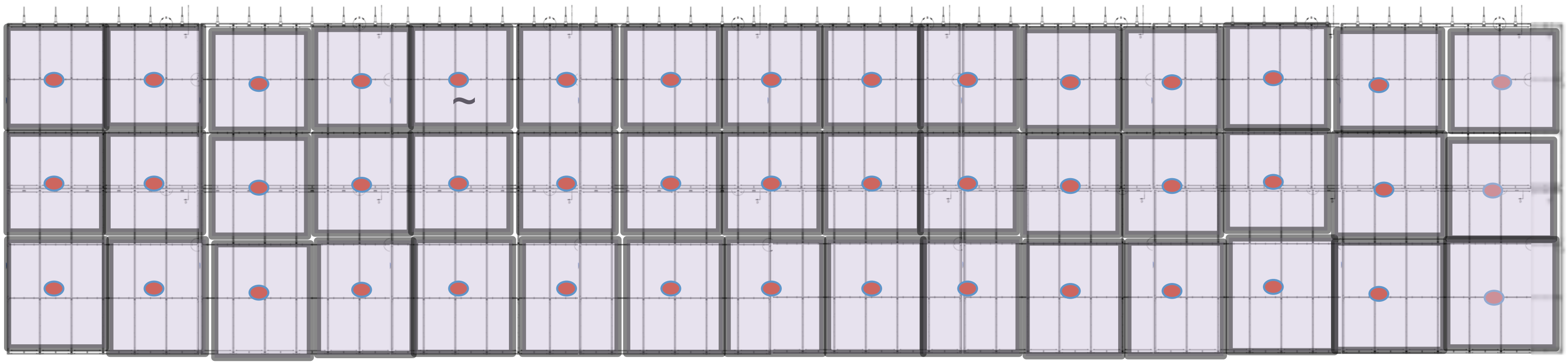


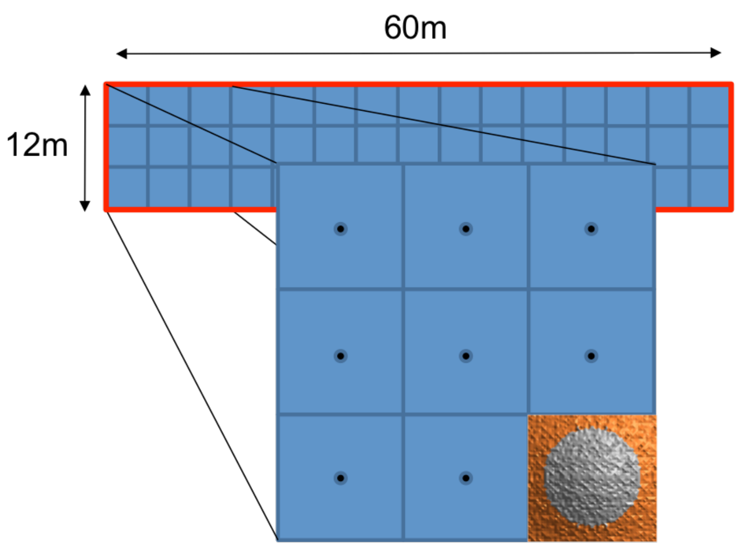


- Simulation shows a single diffuser at CPA will illuminate 4x4 m^2 on APA
- We would need overlap of photons from adjacent diffusers for cross calibration
- This configuration offers that opportunity

DUNE photon monitoring system

- Side view of one DUNE CPA Panel
  - ➢ 45 fibers per CPA side





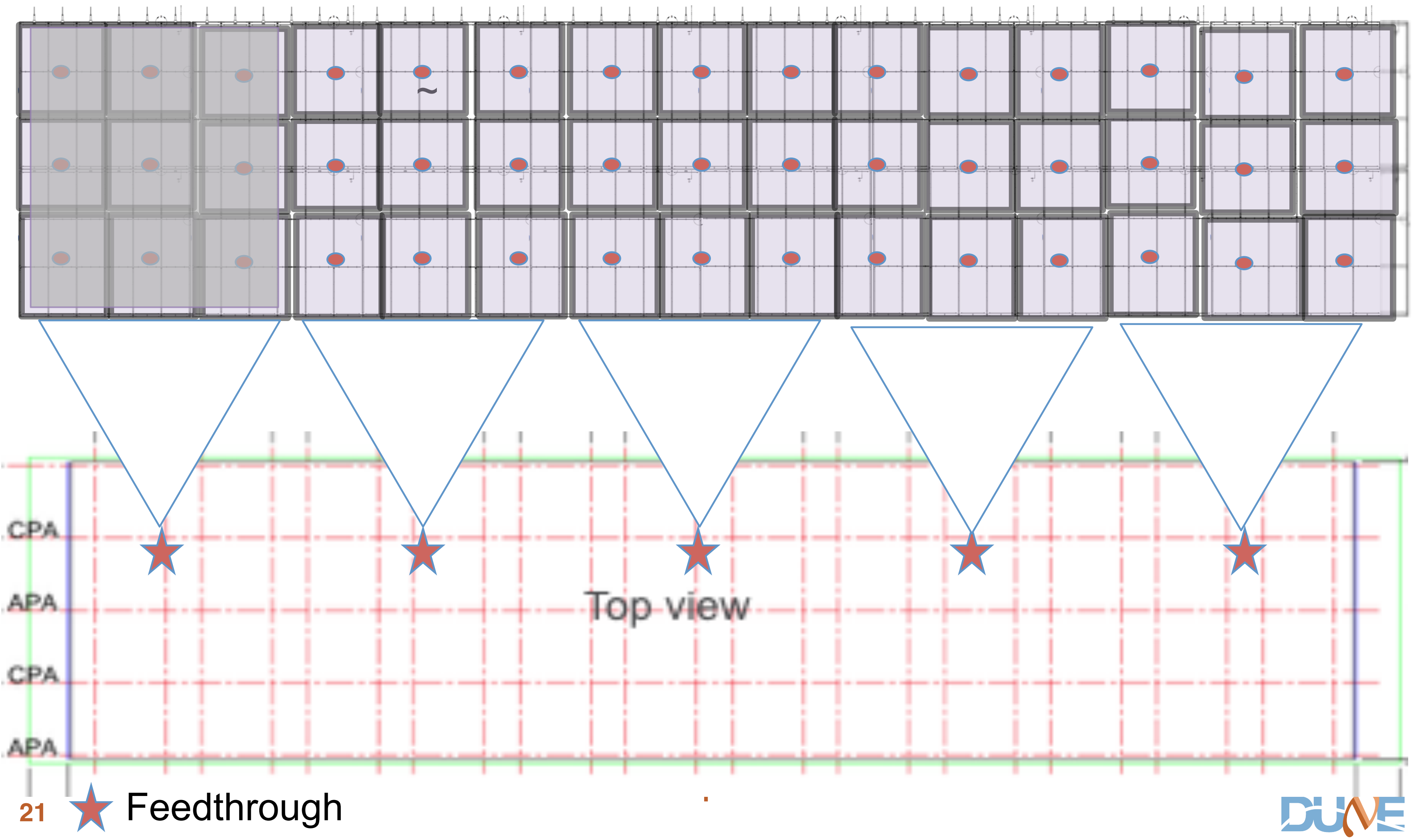
- Simulation shows a single diffuser at CPA will illuminate 4x4 m^2 on APA
- Configuration offers opportunity to overlap photons from adjacent diffusers for cross calibration

➢ ProtoDUNE data are being analyzed and will help verify optimal distribution of light sources across the CPA

DUNE photon calibration system

- 45 fibers (calibration channels) per CPA side
- For 3 CPA sides we would have 135 calibration channels

-assumes middle APA is equipped with X-ARAPUCAs that “see” the light from both sides



Summary and Plans going forward

- Analyze ProtoDUNE photon-detector data calibration/monitoring runs to provide feedback for DUNE
  - -Verify optimal distribution of light diffusers at CPA for DUNE
  - -Use the system to evaluate gain/timing resolution, perform relative comparison of photon technologies/channels.
  - -Characterize and monitor stability of photon system over duration of ProtoDUNE
- Continue work with HV/CPA group
  - -identify optimal materials and locations of photon diffusers at CPA
  - -define fiber routes and connector locations at CPA
  - -define diffuser/fiber installation procedures
- Continue interface discussion with Cryostat/DSS group
  - -identify feed-through ports/locations
  - -define fiber routes along DSS
- Identify/define support for the following
  - -adding feed-throughs to cryostat drawings, diffuser/fiber to CPA/HV drawings
  - -diffuser material selection, prototyping, production and QA/QC testing
  - -fiber selection, prototyping, production and QA/QC testing
  - -identify, test and procure VUV light sources
  - -evaluate ProtoDUNE calibration module design for DUNE
  - -productions and testing of calibration modules
  - -define integration and installation of system components

BACKUP SLIDES

Review Charge

1. Does the design address detector requirements: performance, installation, grounding, testing, calibration, commissioning, operation and maintenance? Are the impacts of detector capabilities and goals on physics performance well documented?

2. Are results from R&D well understood and documented?
   - How well do relevant functional parameters measured from ARAPUCA detector characterization tests match simulations and/or calculations?
   - Has the ARAPUCA light collector concept been demonstrated to meet the performance requirements with a satisfactory safety margin?
   - What additional performance improvements may be realized prior to the TDR/Pre-production review?
   - Is there a well-defined R&D plan to achieve the optimal performance?
   - Is sufficient information available from the readout electronics R&D to ensure that the readout requirements will be met?
   - Is the performance of the gain monitoring system well enough understood to judge if it is needed in DUNE?
   - Are components adequately qualified for operation in liquid argon?

3. Do preliminary engineering drawings, schematics and models provide sufficient information to ascertain constructability and functionality?

Review Charge (cont.)

4. Have interfaces with other detector components been identified and addressed? Are the interfaces with the cryostat, APA, HV, DSS and CE well defined and understood?

5. Have sufficient prototype tests been performed/planned to demonstrate the viability of the design? Have preliminary engineering calculations been planned or conducted to validate the design?

6. Are installation plans in accordance with detector requirements, and are similarities and differences to ProtoDUNE taken into account?

7. Have appropriate manufacturing methods been identified and rough cost estimates and schedule been determined? Are plans for required resources consistent with scope of work?

8. Are operation conditions listed, understood and comprehensive? Is there an adequate calibration plan?

9. Have issues from the ProtoDUNE-SP Photon Detector Review held August 2, 2016 (https://indico.fnal.gov/event/12081/) been appropriately addressed?

9. Have issues from the ProtoDUNE-SP Photon Detector Review held August 2, 2016 (https://indico.fnal.gov/event/12081/) been appropriately addressed?

The following text has been copied from August 2, 2016 ProtoDUNE-SP Photon Detector Review:

Is there an adequate calibration plan?
Answer: Partly.

Finding:
A UV-LED/optical fiber/diffuser system will have diffusers mounted on the CPAs.

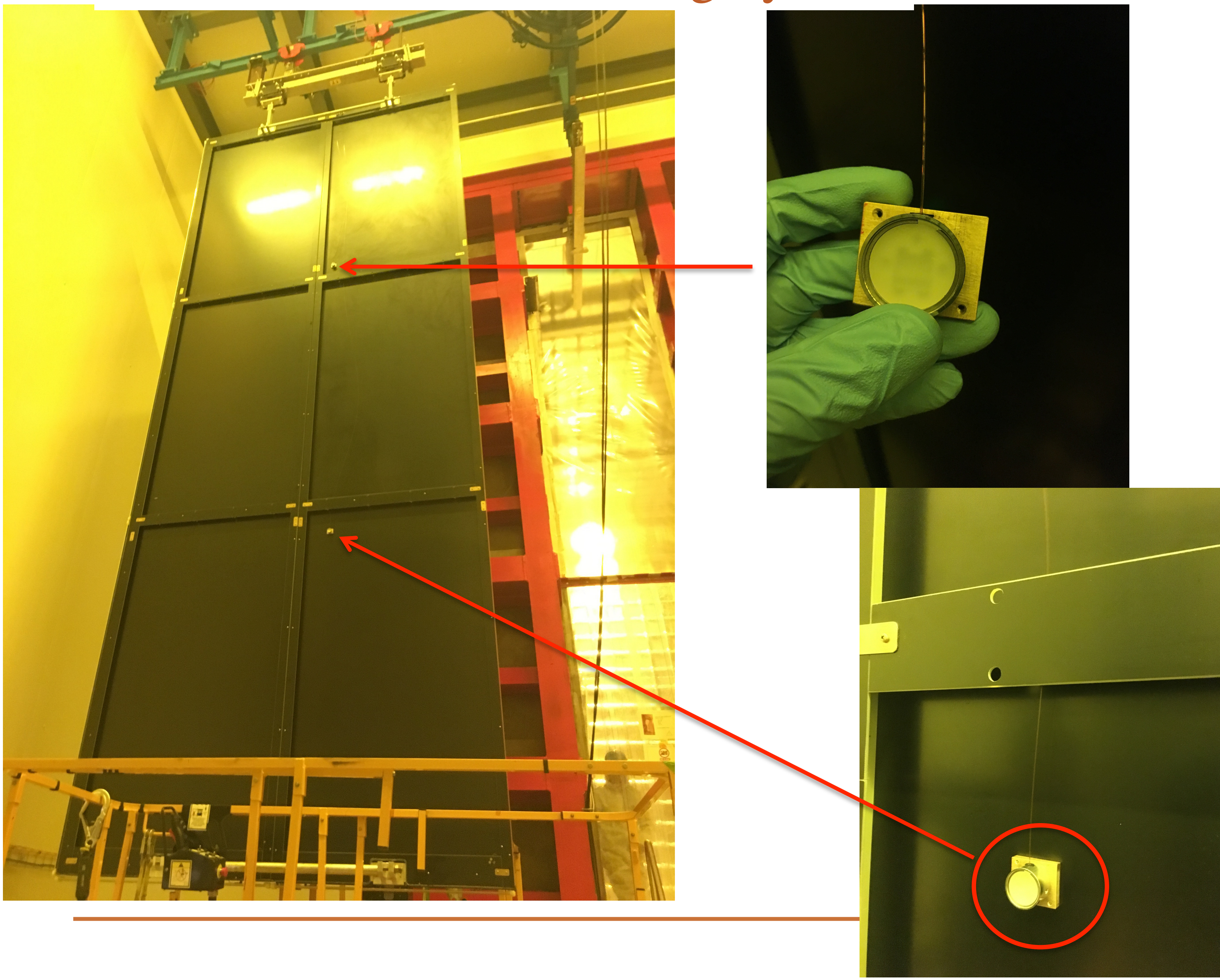
Comment:
The design of the UV-LED system is nearing completion and was presented in detail to us. The LED system is more a monitoring system (devices working and stable) than a calibration system.

⇒ *Here we describe the system to monitor "health" of the photon system and its gain and time-resolution*

Recommendation:
A calibration plan, including, for example, channel-to-channel timing offsets, *t*0 timing for the TPC, light yield and resolution vs. 3D position, should be developed.

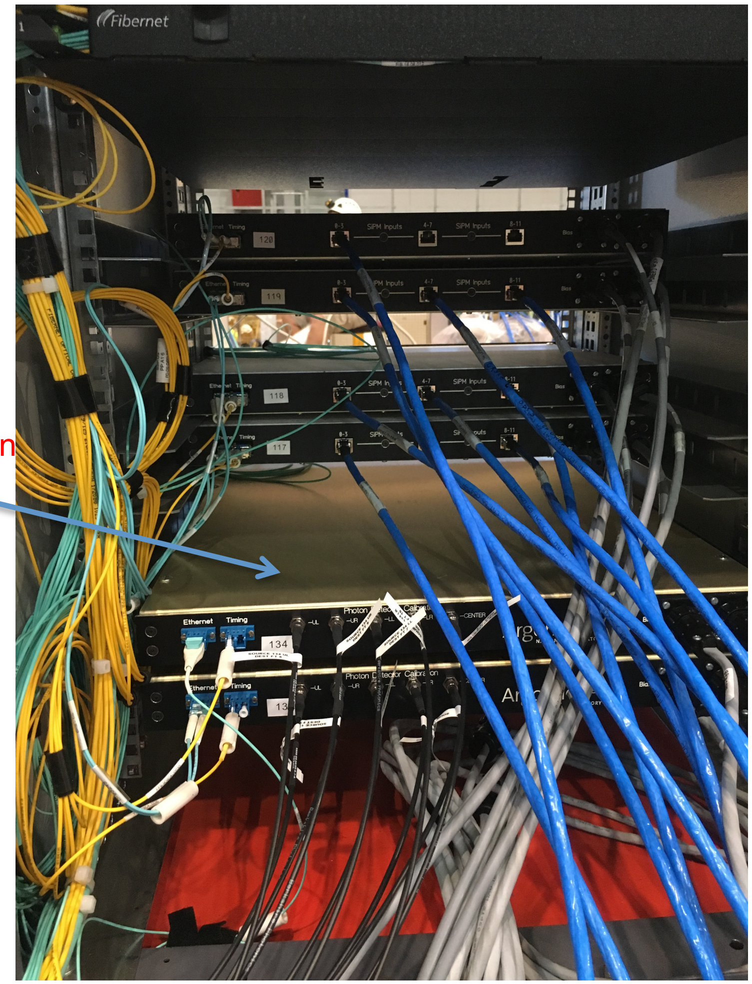
⇒ *This system evaluates channel-to-channel timing offsets but the TPC calibration plan and quantification of light yield and resolution vs. 3D position is being developed through Calibration Consortium*

ProtoDUNE-SP Monitoring System

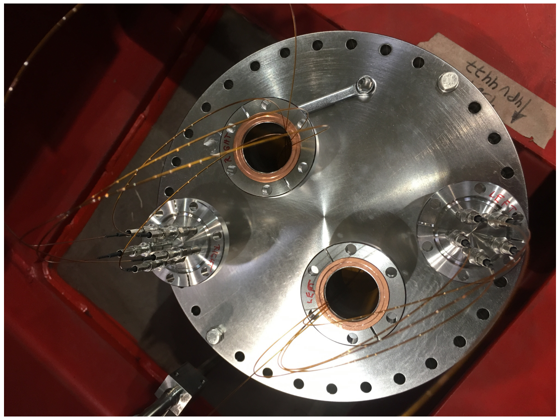


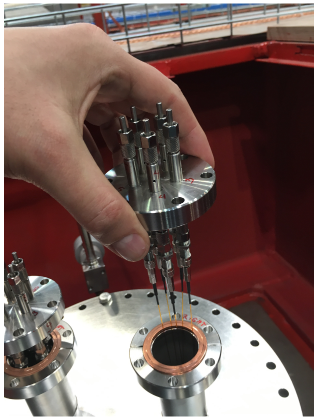
ProtoDUNE-SP Monitoring System

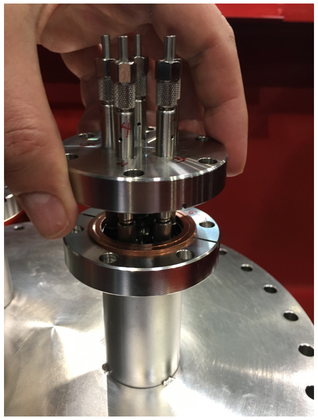
Two Calibration Modules

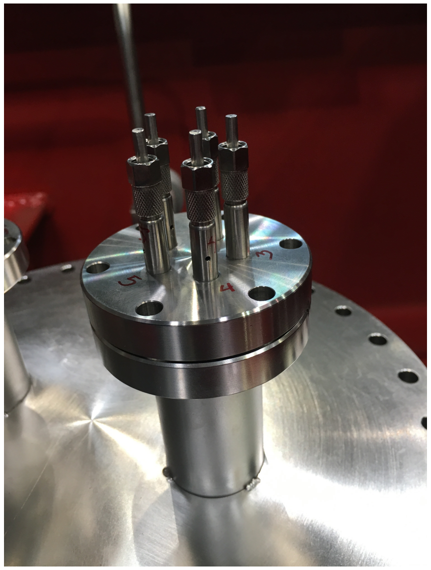


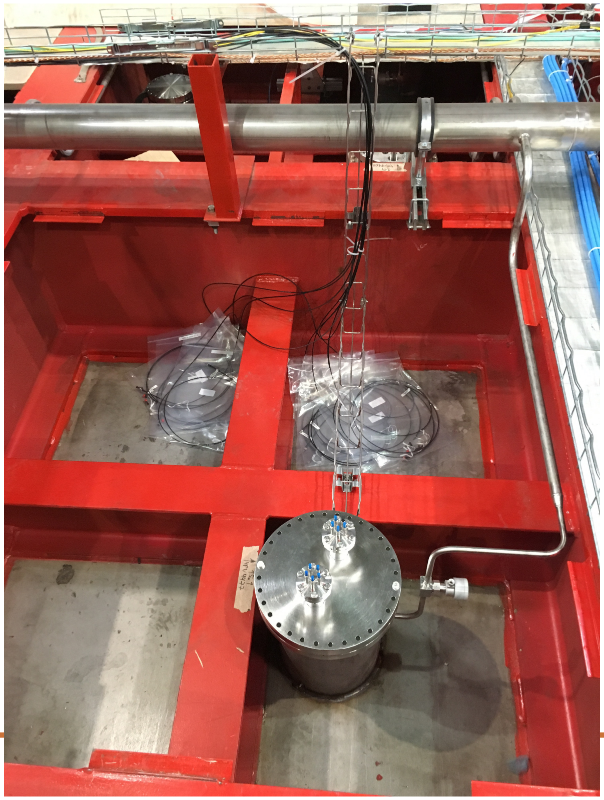
ProtoDUNE-SP Monitoring System

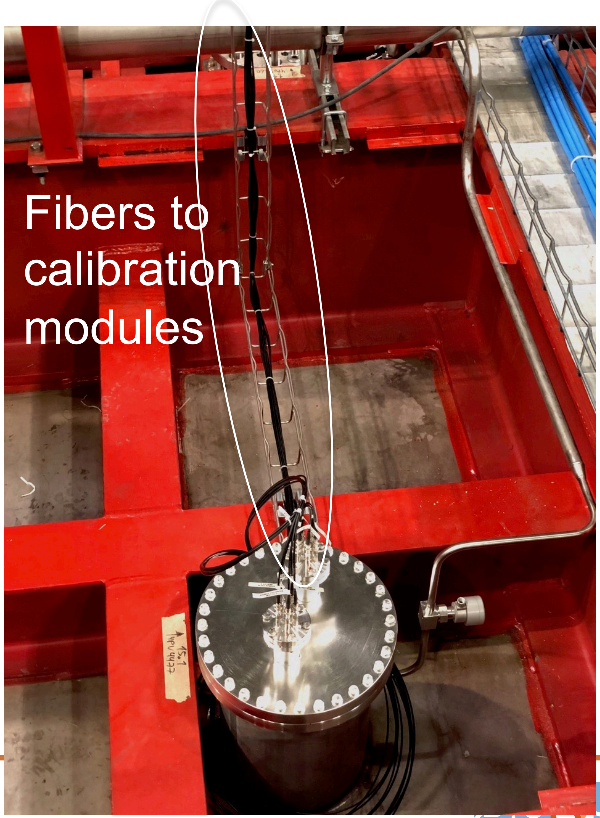




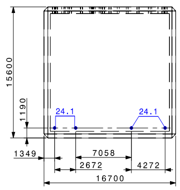




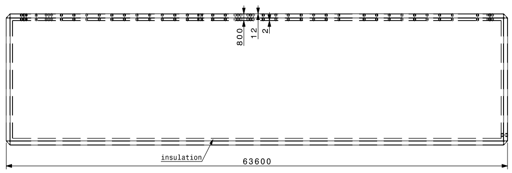


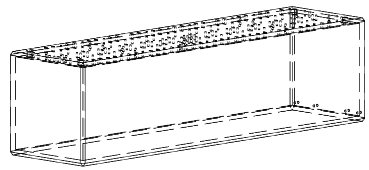


Right view
1:200



Front view
1:200





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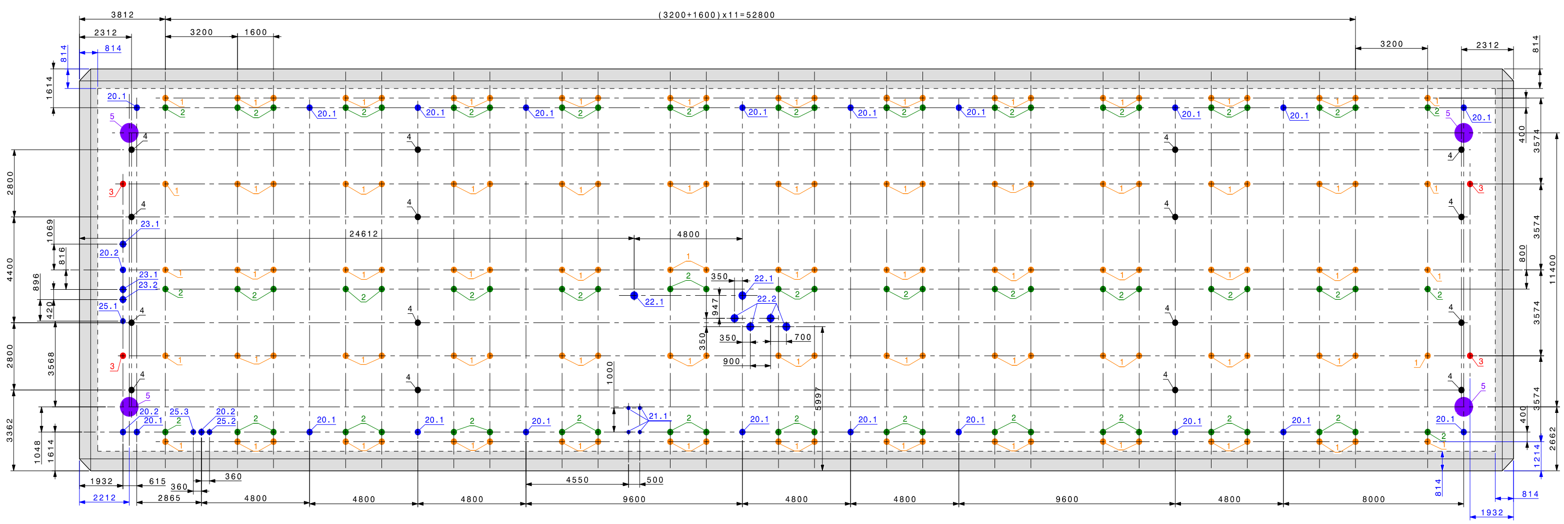
22.2		4	G Ar Relief/Safety
23.1	Ø273	2	L Ar Return
23.2		1	L Ar Emergency return
24.1	Ø350	4	L Ar Pump
25.1	Ø219	1	G Ar Purge
25.2		1	G Ar Make up
25.3		1	G Ar Momentum

Top view
1:70



LBNF Cryostat		DRAWN	E. SELETSKAIA	2017-07-09
LBNF PENETRATIONS VERTION 2	SCALE 1:1	CONTROLLED		
		RELEASED		
		APPROVED		
		CAD Document Number	ST0858074_04	
		REPLACES		
NON VALABLE POUR EXECUTION / NOT VALID FOR EXECUTION	QAC -	CENBNFCR0073	SIZE 0	IND.

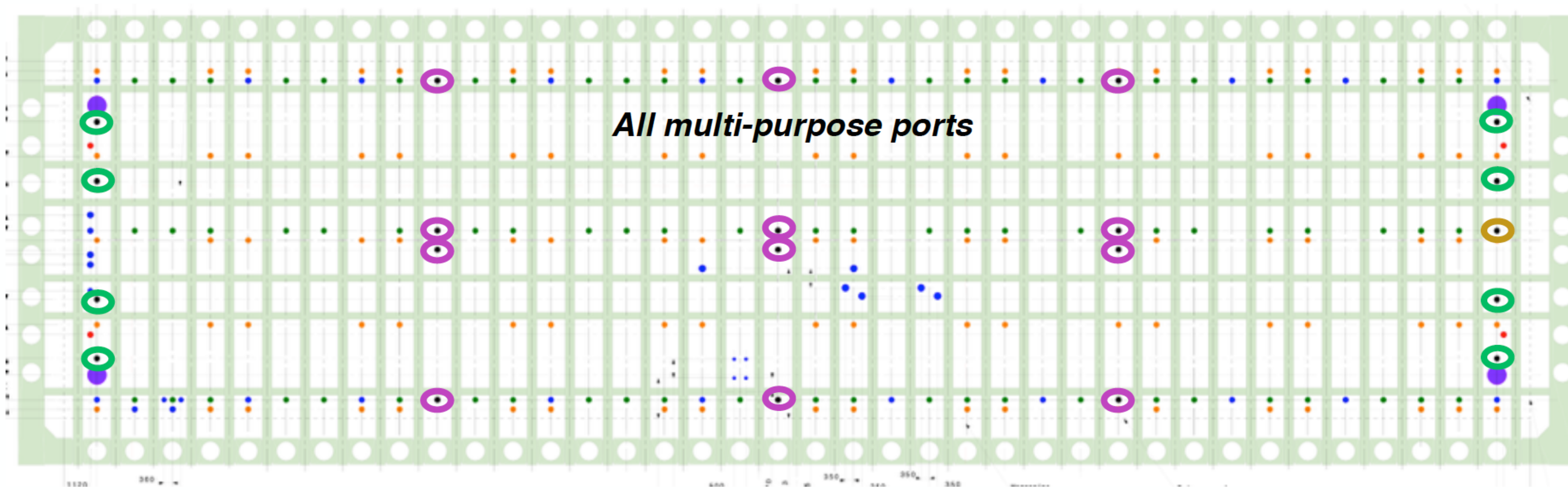
DUNE FD Cryostat Penetrations

Slide from Sowjanya's DUNE Collaboration Meeting talk:
https://indico.fnal.gov/event/14581/session/0/contribution/10/material/slides/0.pdf

= Calibration FTs

= Calibration FT (outside the FC)

= Cryogenic Instrumentation FT



Pos.	Diameter [mm]	Quantity	Description
1	Ø250	100	Support
2	Ø250	75	Cable
3	Ø250	4	High voltage
4	Ø250	21	Instrumentation
5	Ø800	4	Manholes

Laser FTs (Magenta & Green) every 14 m or so. 10 m laser range demonstrated in MicroBooNE.

DUNE FD Cryostat Structure

- Use Detector Support Structure (DSS) drawings to orient ourselves